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MODEL 8726H TRAVELING WAVE TUBE.(U)
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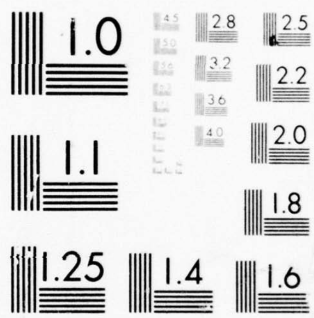

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RADC-TR-77-344
Final Technical Report
November 1977

MODEL 8726H TRAVELING WAVE TUBE

Hughes Aircraft Company

Approved for public release; distribution unlimited.

ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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19 REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER 18

RADC-TR-77-344

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle) 6

MODEL 8726H TRAVELING WAVE TUBE.

5. TYPE OF REPORT & PERIOD COVERED 9

Final Technical Report,
January 1976 - July 1977,

6. PERFORMING ORG. REPORT NUMBER

N/A

7. AUTHOR(s) 10

Dr. C. A. Ar

8. CONTRACT OR GRANT NUMBER(s) 15

F30602-76-C-0105 New

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Hughes Aircraft Company
3100 West Lomita Boulevard
Torrance CA 90509

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

P.E. 62702F
J.O. 55730206 17 02 16

11. CONTROLLING OFFICE NAME AND ADDRESS 11

Rome Air Development Center (OCTP)
Griffiss AFB NY 13441

12. REPORT DATE

November 1977

13. NUMBER OF PAGES

46

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

Same 12 52p.

15. SECURITY CLASS. (of this report)

UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer: Leon Stevens (OCTP)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Microwave
Amplifier
Traveling Wave Tube
X-band
Coupled Cavity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the development of a coupled cavity traveling wave tube with the following specifications. Gain - 53 dB; Pulse Length - 200 microseconds; Modulation - Shadow Grid (less than 700 nanoseconds rise and fall times); Focusing - PPM; Efficiency - 25 percent minimum; Phase Linearity - Plus and minus 10 degrees.

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EVALUATION

In addition to its primary function of providing a 20 kilowatt peak power tube over the 7.9 to 8.4 GHz SATCOM band, this tube also incorporates PPM focusing for weight reduction, a beam scraper for increased reliability, and collector depression to increase efficiency. It should be noted that after the final design was generated based on cold test data the first tube constructed and hot tested met or exceeded all of the original specifications and design goals. This tube should therefore provide an excellent design which may be scaled to fill the exact needs of any future TDMA SATCOM system.

Leon Stevens
LEON STEVENS
Proj Engr/OCTP

FINAL REPORT 8726H

This document describes the progress made in fulfilling the terms of Rome Air Development Center Contract F30602-76-C-0105 through the program conclusion. The contract had as its objective the design, development, fabrication and delivery of one high power X-band traveling-wave tube for TDMA SATCOM application. The TWT was assigned the model number 8726H.

1. PROGRAM STATUS

The program has been completed in accordance with the two appended schedules (Figure 1 and Figure 2). All objectives were achieved. A description of the TWT design features and operating parameters is given in Section 2; a discussion of test results is given in Section 3.

2. DESCRIPTION OF THE 8726H

2.1 *DESIGN FEATURES*

The 8726H is an X-band coupled cavity TWT with an instantaneous bandwidth from 7.9 to 8.5 GHz and a duty capability of 5%. The salient design features of the tube are listed below:

Shadow Gridded Gun

Beam Scraper

Coupled Cavity Circuit

Single-Stage Depressed Collector

PPM Focusing

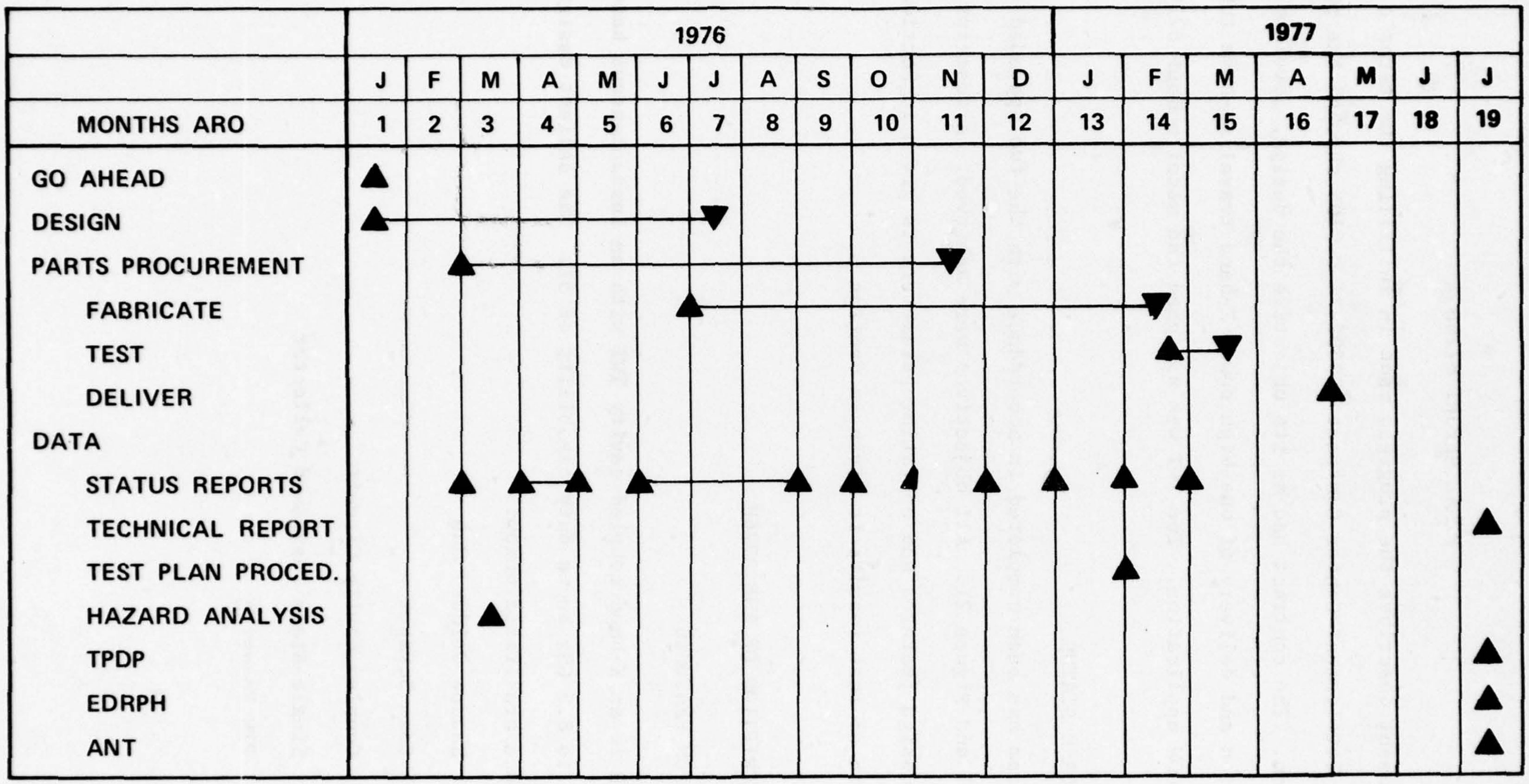

Figure 1 Program Schedule

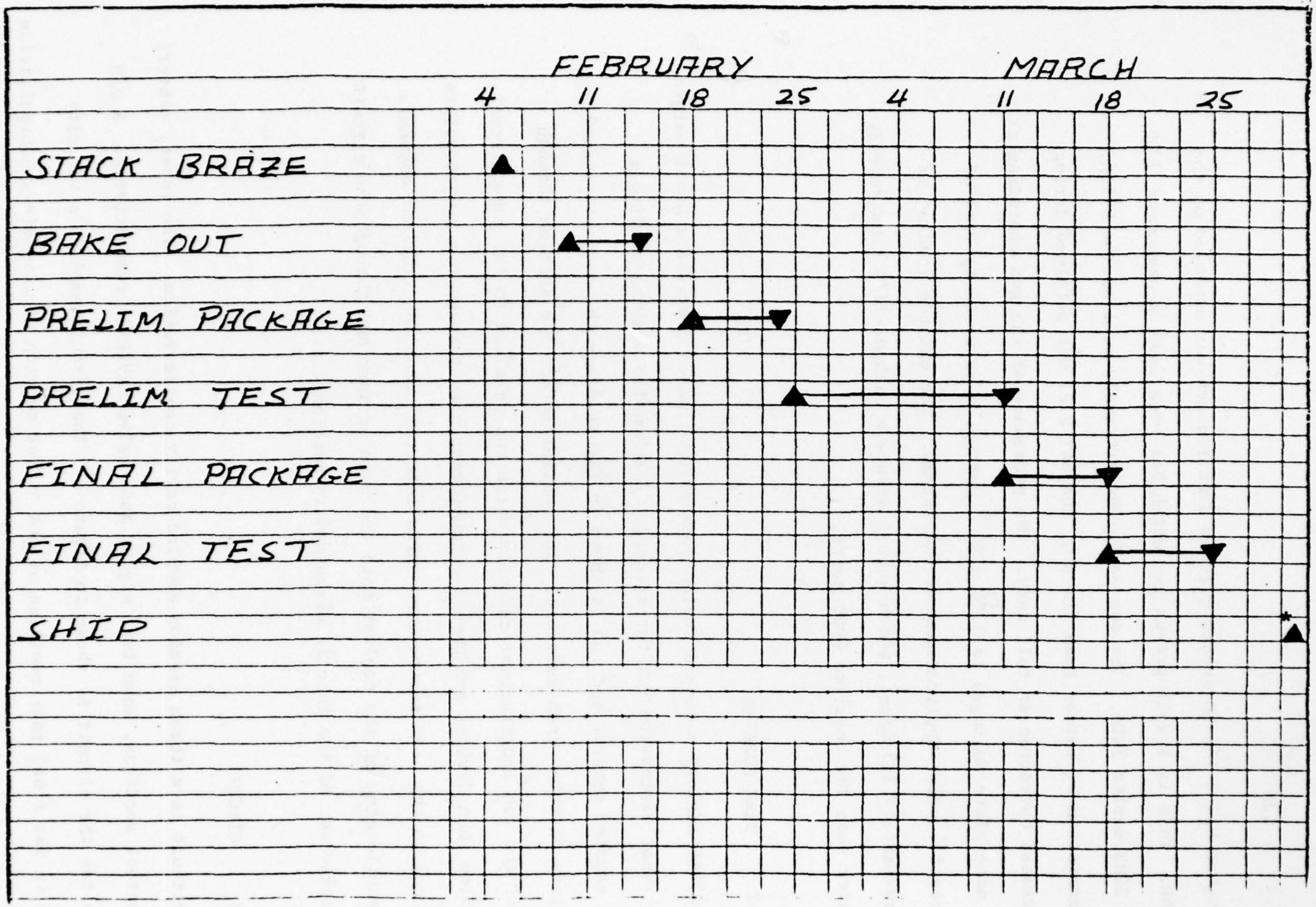

Figure 2 Fabrication Schedule

2.1.1 GUN

A Hughes Model 162-BG shadow gridded electron gun was employed on the 8726H. This is a well proven gun which has been used on numerous 751H and 308H series TWTs. The gun performed extremely well on the 8726H. Transmission of better than 91% D.C. and 84% R.F. was obtained during depressed operation at full duty. The perveance of the gun operating at the name plate voltages is 1.28×10^{-6} μpervs, a value of typical of successful prior applications of the 162-BG. The cathode loading is approximately 3.5 A/cm^2, which should assure a cathode life considerably greater than the required 2000 hours.

2.1.2 BEAM SCRAPER

The 8726H employs a liquid cooled beam scraper which provides a great margin of thermal protection for the circuit. A schematic drawing showing a beam scraper circuit section is shown in Figure 3 --- the complete assembly consists of three such sections. The coolant enters the section through one of the two longitudinal channels which run parallel to the tube circuit. The flow then divides and passes circumferentially through the fin structure internal to the beam scraper and exits into the other longitudinal channel. The manifolding of the coolant into the beam scraper and through the circuit and collector of the tube is discussed in Section 2.1.3.

2.1.3 CIRCUIT

The circuit is a three section coupled cavity configuration. The input, center, and output sections, have ten, eight, and twelve cavities respectively. A ω/β curve for the circuit is shown in Figure 4. The circuit employs a velocity taper in the final four cavities of the output section to maintain synchronization

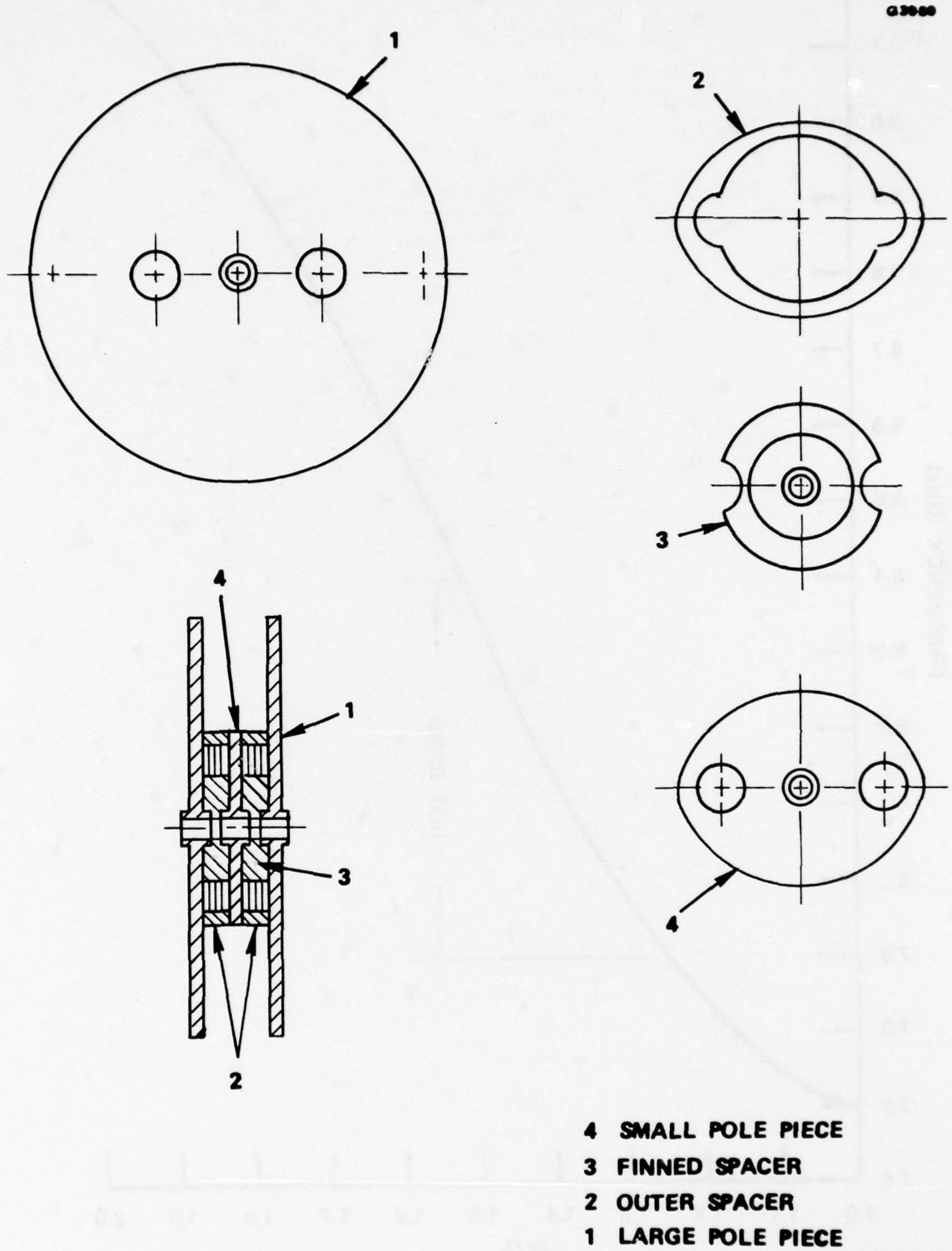

Figure 3 Beam Scraper

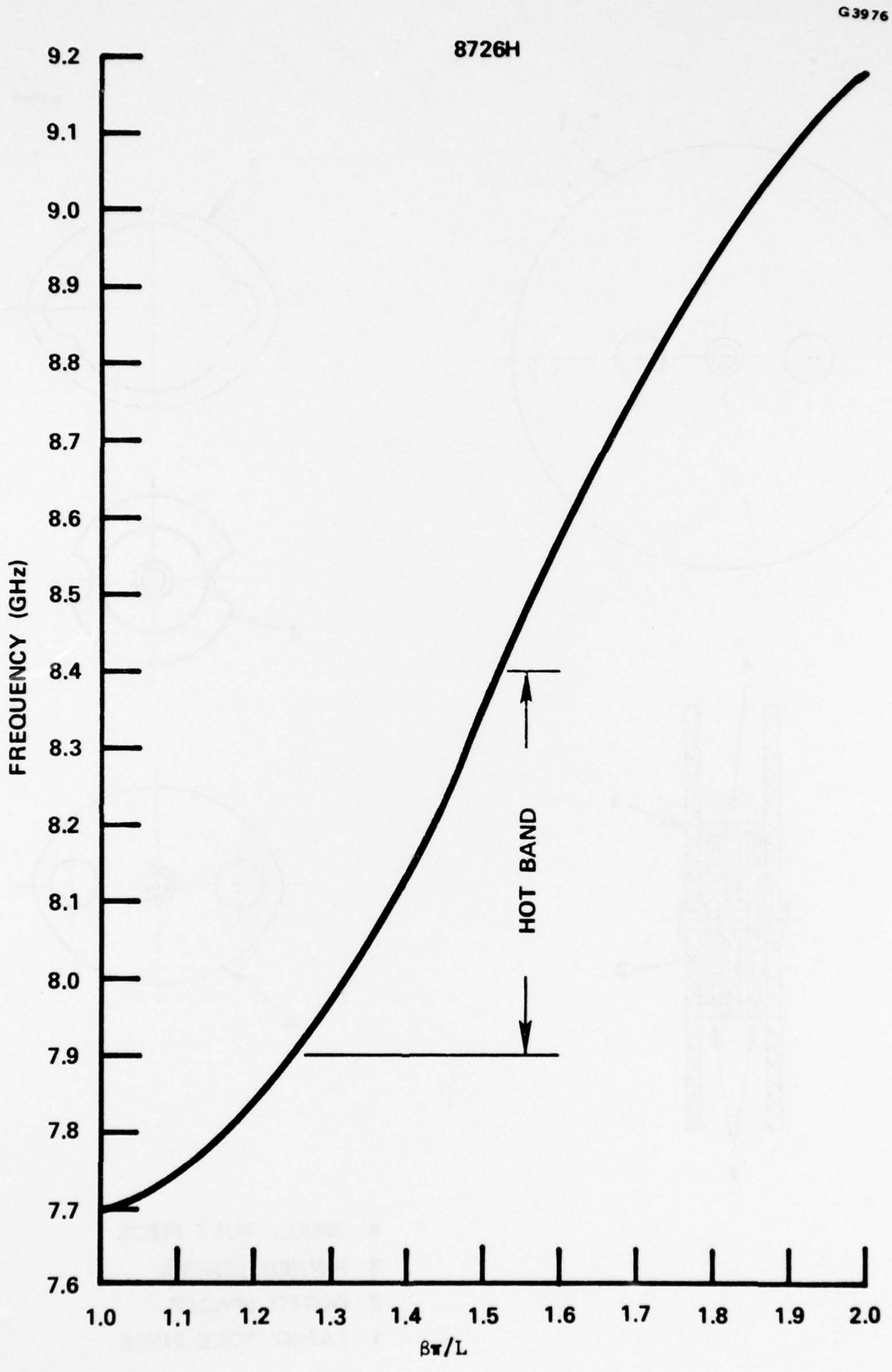
G3976
8726H
9.2
9.1
9.0
8.9
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
FREQUENCY (GHz)
HOT BAND
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
βπ/L

Figure 4

of the electron beam velocity and RF phase velocity. Loss buttons are included in all but the final two circuit cavities to suppress oscillation at upper cutoff.

Because of the large amount of thermal dissipation which takes place in the circuit while the tube is operated at the relatively high 5% duty cycle, channeled pole pieces were used in the last six positions of the output circuit section (the region of highest dissipation). These pole pieces permit the FC-77 coolant to flow close to the ferrules of the circuit and provide a very comfortable margin of thermal safety. Three additional channeled pole pieces were used in the input section primarily for manifolding purposes.

A schematic drawing is provided in Figure 5 to show the overall coolant manifolding scheme. The flow enters the tube through a coolant inlet assembly on the gun pole piece. A special coolant inlet spacer manifolds the fluid into one of the two longitudinal channels. The flow block shown in Figure 5 at the end of the beam scraper section forces the flow through the beam scraper fin structures, as discussed earlier. The flow then passes through one of the longitudinal channels into the circuit portion of the tube. A flow block of this channel at the collector pole piece causes the flow to pass through the nine channeled pole pieces as indicated in the sketch. A 2/3 - 1/3 flow division between the two longitudinal channels in the center section of the circuit is achieved by locating three channeled pole pieces in the input section and six in the output section (the channeled

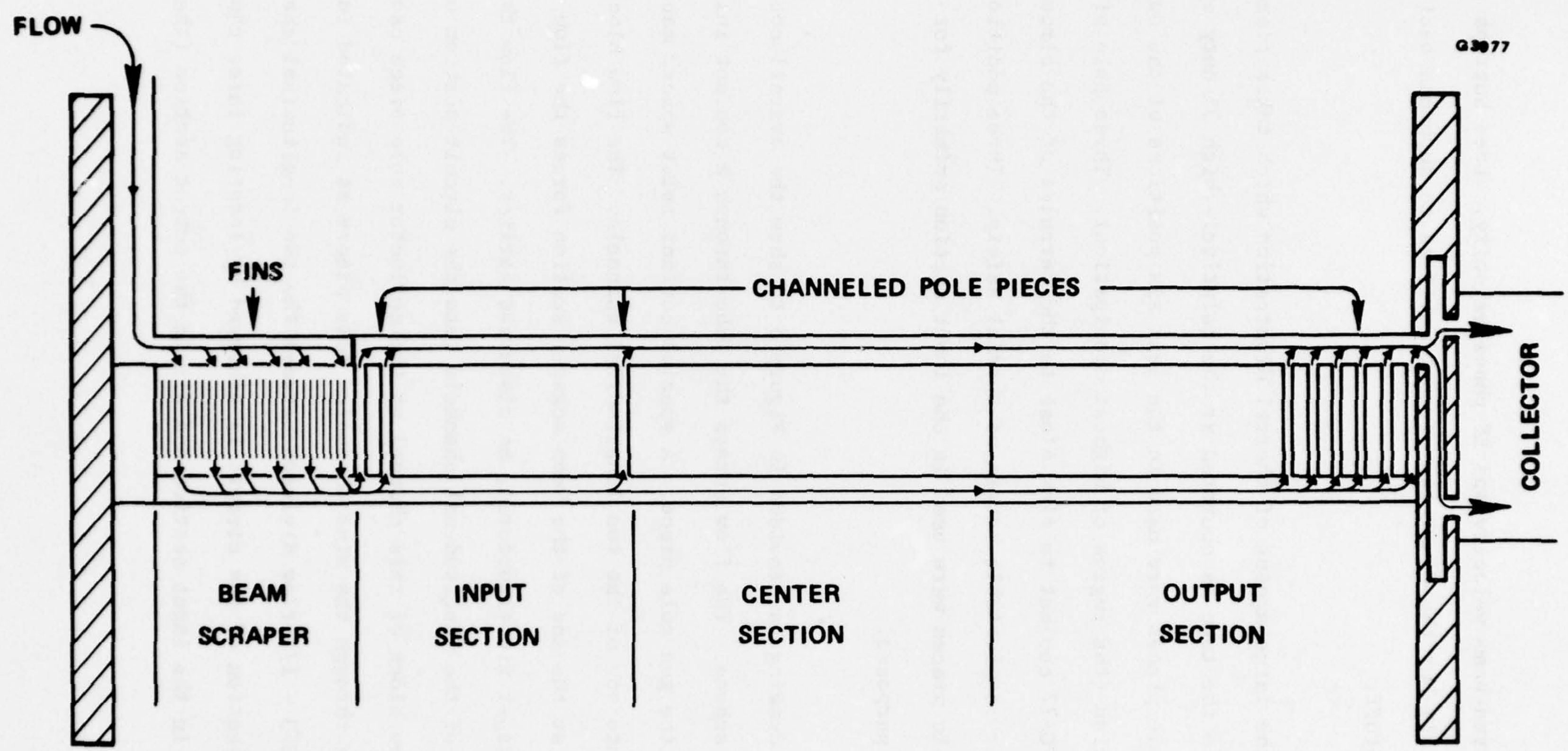

Figure 5 Coolant Flow Diagram

pole pieces have high flow impedance relative to the main channels). This provides adequate cooling along the circuit, and causes the majority of the flow to pass through the pole pieces in the output section where the thermal dissipation is greatest. The flow then proceeds through the collector pole piece into the collector fin structure, and exits from the tube through the collector can.

2.1.4 COLLECTOR

The collector used on the 8726H is shown in Figure 6. The electrical characteristics of the collector are excellent. Figure 7 shows the center band efficiency of the 8726H as a function of collector depression. The name plate depression of -10 kV was selected because it provided more than adequate efficiency while subjecting the circuit to a relatively small thermal load (at higher depression the amount of current returned to the circuit increases).

The cooling is achieved with an array of circumferential fins which surround the cylindrical exterior surface (these can be seen in Figure 6). The coolant flow is manifolded into the fin structure through three longitudinal channels. The flow then divides and flows around the outside diameter of collector surface to three channels on the opposite side. There is one internal flow reversal before the fluid exits. This thermal design is extremely rugged. It has been destructively tested, and demonstrated a power handling capability in excess of 15 kW. In the present application the

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Figure 6 Photograph of 8726H collector.

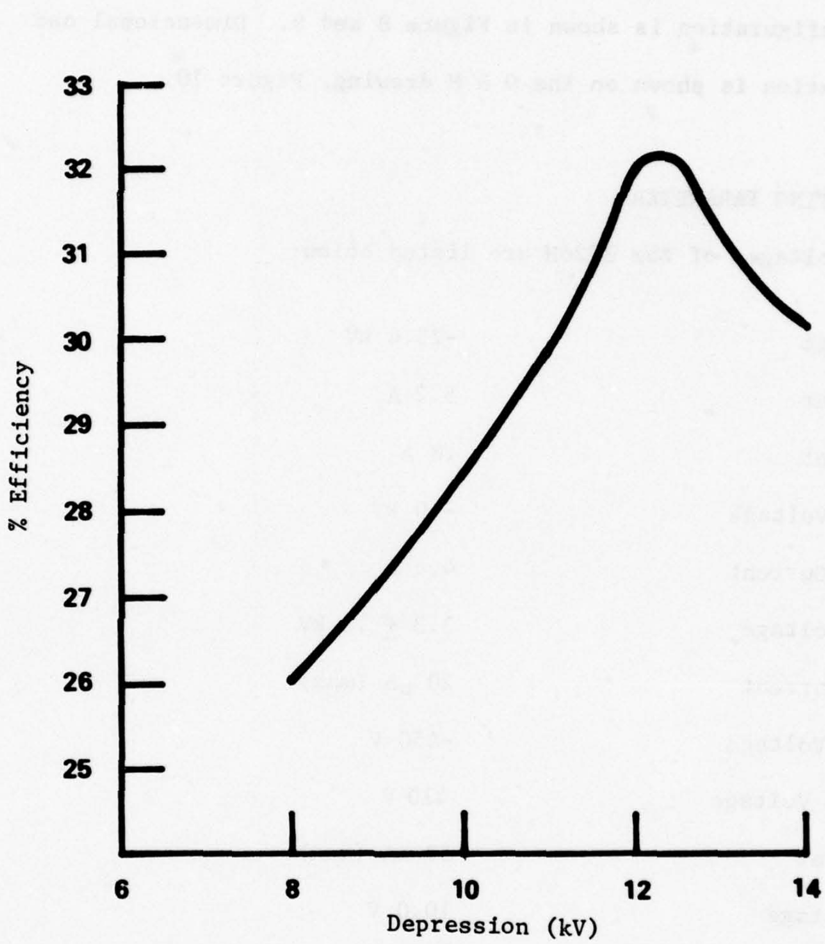

Figure 7 8726H centerband efficiency.

collector subjected to less than half this power under the most severe conditions, i.e., operation without RF or depression.

2.1.5 PACKAGE

The external configuration is shown in Figure 8 and 9. Dimensional and mounting information is shown on the O & M drawing, Figure 10.

2.2 OPERATING PARAMETERS

The operating voltages of the 8726H are listed below:

Beam Voltage	-25.4 kV
Beam Current	5.2 A
Body Current	.8 A
Collector Voltage	-10 kV
Collector Current	4.4 A
Ion Pump Voltage	3.3 ± .3 kV
Ion Pump Current	20 μA (max)
Grid Bias Voltage	-450 V
Grid Pulse Voltage	410 V
Grid Current	50 mA (max)
Heater Voltage	10.0 V
Heater Current	5.3 A

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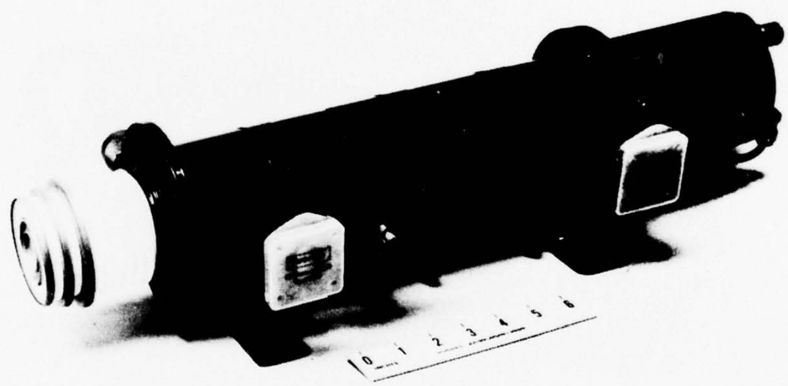

Figure 8   Photograph of the 8726H.

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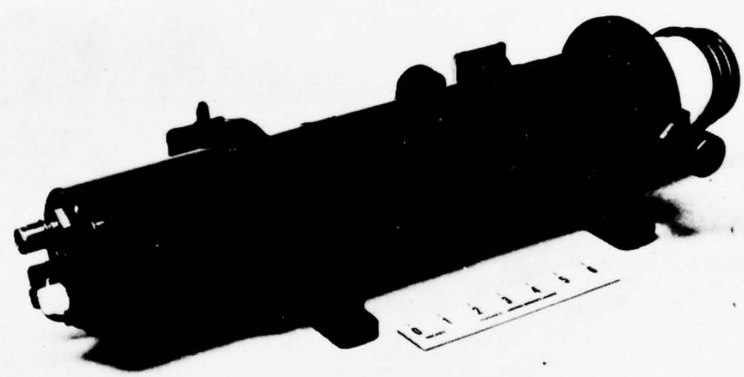
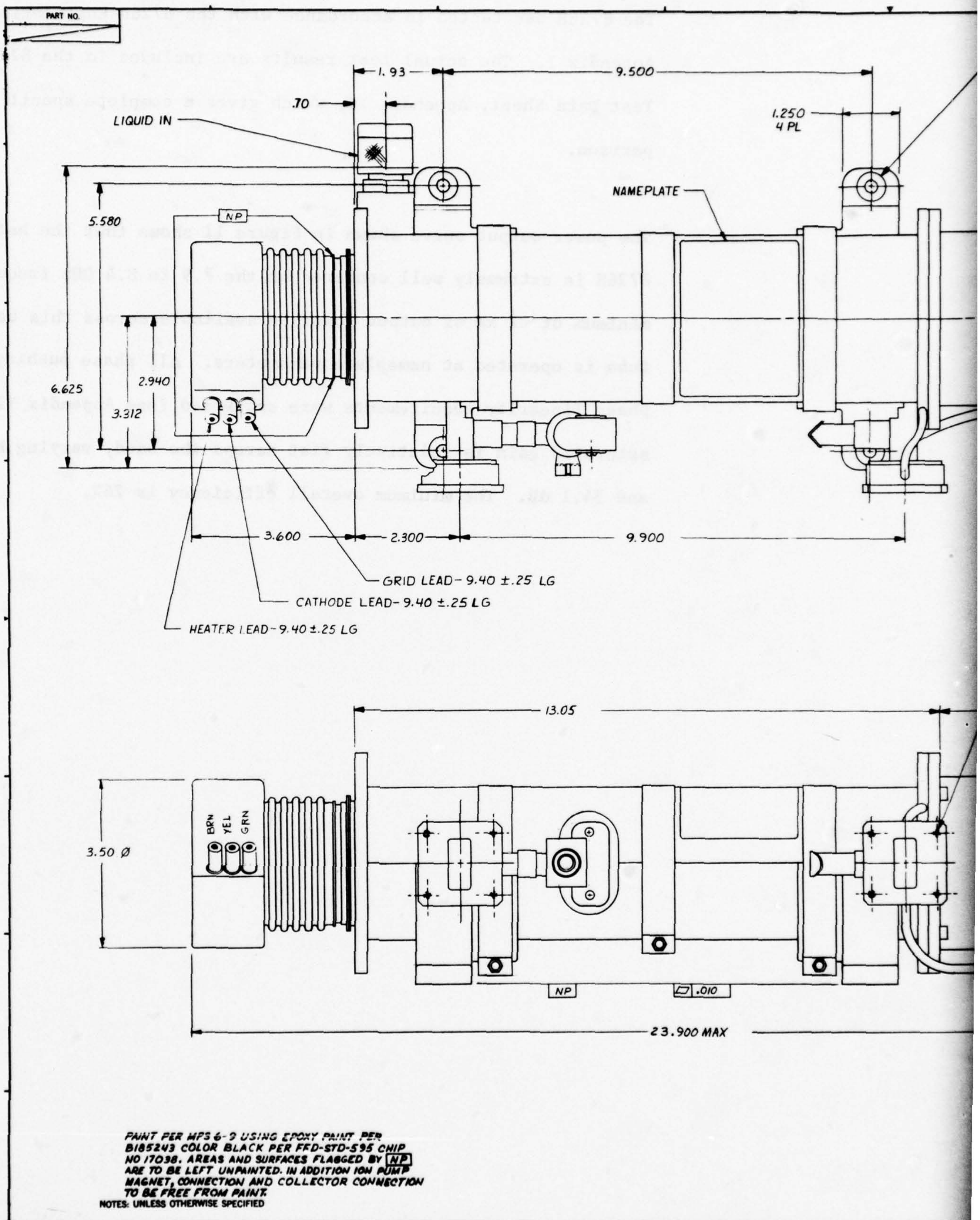


Figure 9 Photograph of the 8726H.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4 PL
NAMEPLATE
5.580
NP
2.940
6.625
3.312
3.600
2.300
9.900
GRID LEAD-9.40 ±.25 LG
CATHODE LEAD-9.40 ±.25 LG
HEATER LEAD-9.40 ±.25 LG
13.05
BRN
YEL
GRN
3.50 Ø
NP
.010
23.900 MAX
PAINT PER MPS 6-9 USING EPOXY PAINT PER B185243 COLOR BLACK PER FED-STD-595 CHIP NO 17038. AREAS AND SURFACES FLAGGED BY NP ARE TO BE LEFT UNPAINTED. IN ADDITION ION PUMP MAGNET, CONNECTION AND COLLECTOR CONNECTION TO BE FREE FROM PAINT.
NOTES: UNLESS OTHERWISE SPECIFIED

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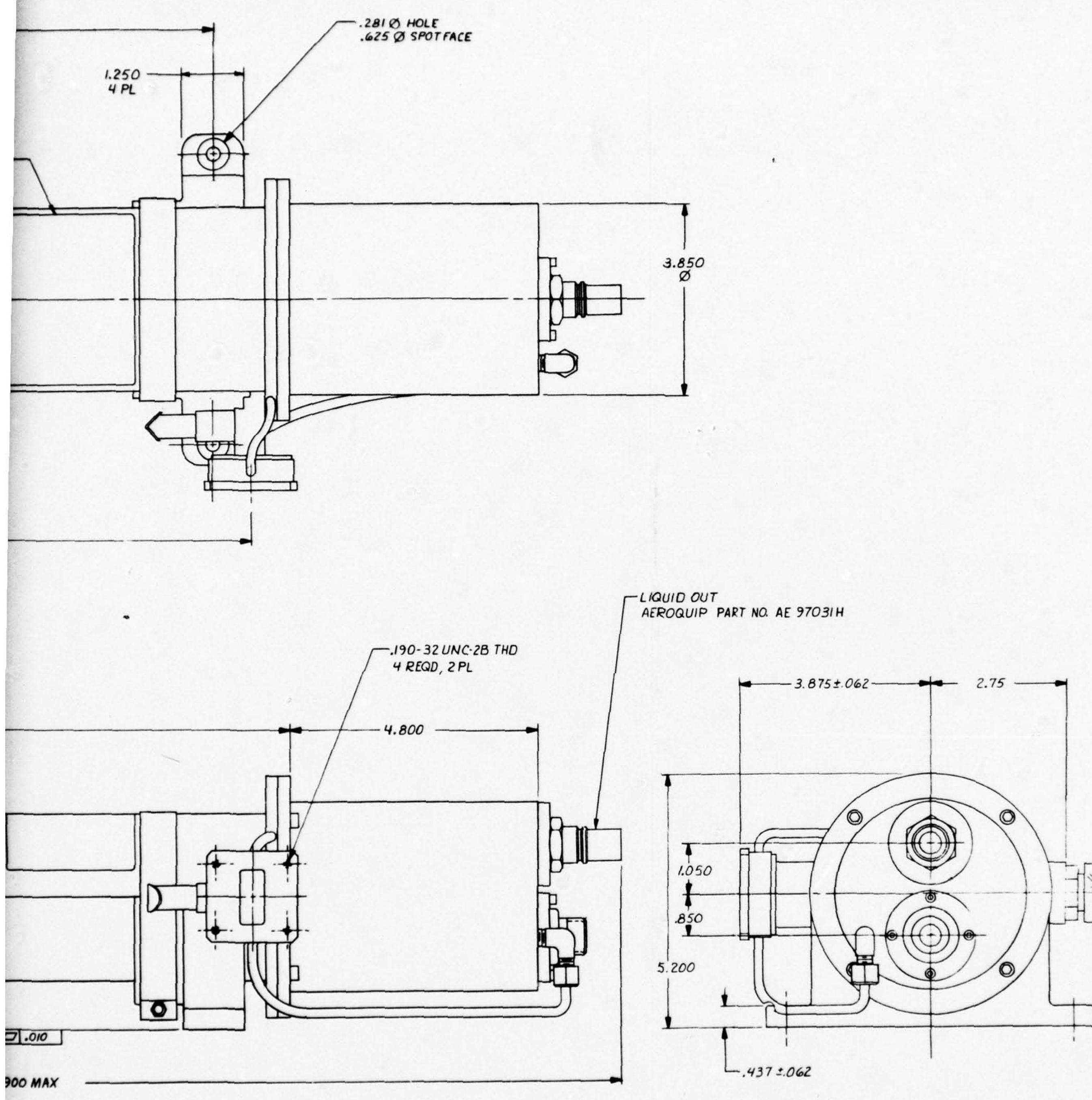

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PARTS LIST

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XXX ±.005 XX ±.02
ANGLES ±0° 30' FINISH 63
EDGES & CORNERS .010 R MAX
MATERIAL

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APPD

HUGHES
HUGHES AIRCRAFT COMPANY
ELECTRON DYNAMICS DIVISION
TORRANCE, CALIF. 90509

INSTALLATION CONTROL DRAWING 8726H

SIZE	CODE IDENT NO.	DRAWING NO.	REV
F	73293	ICB131198	

SCALE 1/1 SHEET 15

3.0 TEST RESULTS

The 8726H was tested in accordance with the 8726H Engineering Test Plan, Appendix I. The actual test results are included in the 8726H Engineering Test Data Sheet, Appendix II, which gives a complete specification comparison.

The power output curve shown in Figure 11 shows that the hot band of the 8726H is extremely well centered on the 7.9 to 8.4 GHz frequency band. A minimum of 22 kW of output power is available across this band when the tube is operated at nameplate parameters. All phase pushing and phase linearity requirements were satisfied (see Appendix II). The saturated gain is relatively flat across the band, varying between 53.4 and 54.1 dB. The minimum overall efficiency is 26%.

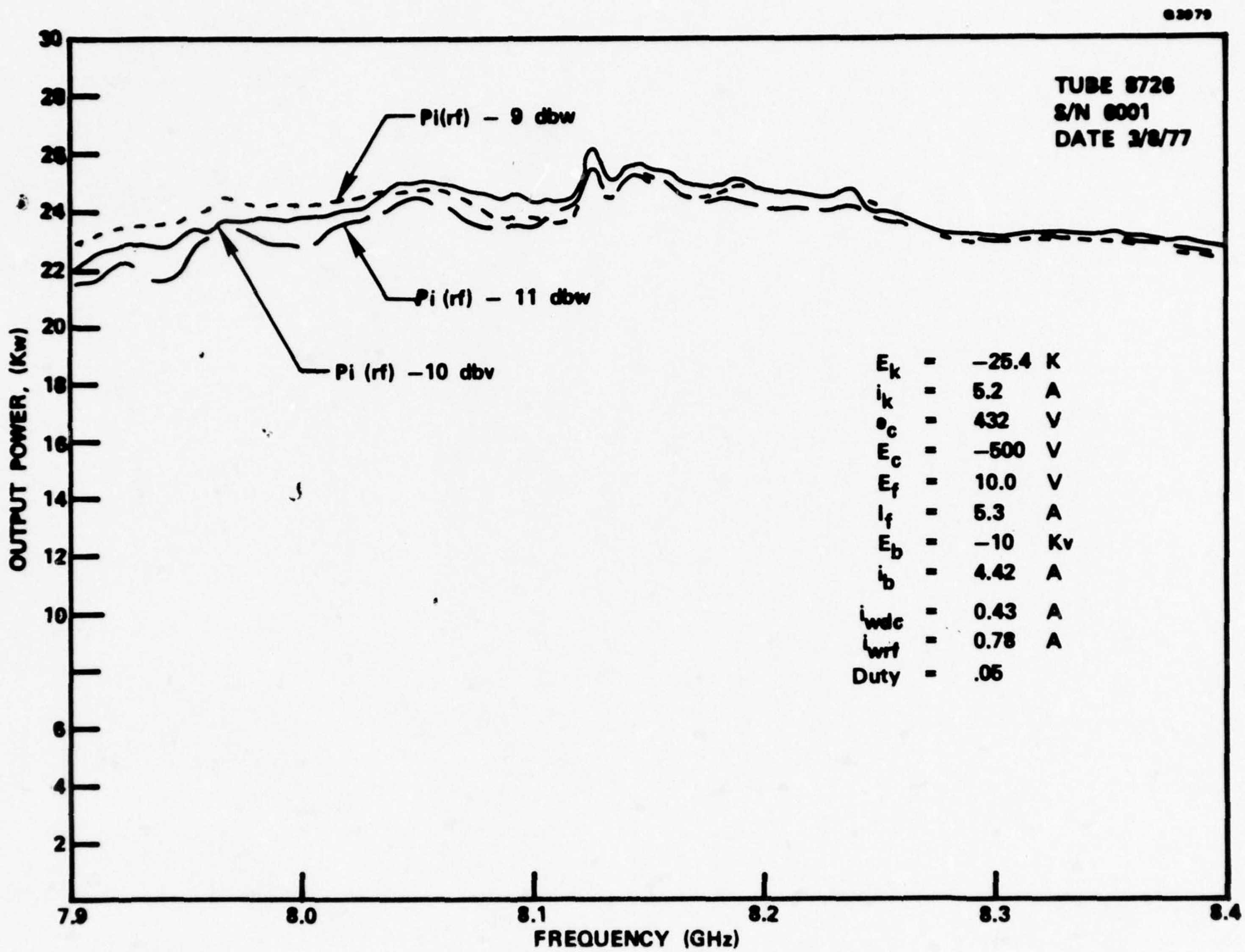

Figure 11 Power vs frequency.

APPENDIX 1

8726H ENGINEERING TEST PLAN

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PREPARED FOR RADC

CONT. NO. F30602-76-C-0105

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ENGR.	C. A. L	ENGINEERING TEST PLAN	
MFG.			
REL.		SIZE A	CODE IDENT NO 73293
DATE OF ISSUE	7 February 1977	REV	SHEET 1 OF 23

EDD 1047F Jun 74

1.0 SCOPE

The purpose of this document is to define the acceptance tests to be performed on the traveling wave tube (TWT).

2.0 APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein.

None

3.0 REQUIREMENTS

Acceptance tests shall be conducted at Hughes Aircraft Company, Electron Dynamics Division (EDD) or other test facilities approved by EDD. RF tests shall be conducted using either swept or point measurement techniques.

3.1 Test Surveillance

Prior to the start of acceptance test, the cognizant representative of the Electron Dynamics Division Quality Assurance and a Government representative or contracting officer shall be notified and shall be present; the cognizant customer representative shall also be notified and may be present.

3.2 Test Results

The results of acceptance tests shall be recorded on acceptance test data sheets which are controlled by this procedure and revisions hereto.

All entries made during acceptance testing must be in ink. Deletions and/or corrections to the data sheets shall be made by ruling out the appropriate portions of the test data and inserting the corrections. Ruled-out data must remain legible and be signed and dated by the person making the correction.

Completed data sheets shall be signed or stamped by the person performing the test.

3.3 Preparation of Data

Copies of test results (Acceptance Test Data Sheets) shall be shipped with the TWT.

3.4 Failure

If a malfunction or out-of-tolerance condition occurs during acceptance tests, it shall be processed in accordance with EDD Nonconforming Supplies Control, Quality Practice 4.5.

3.0 REQUIREMENTS (Cont.)

3.5 Retest

When there is a modification, repair, or rework after acceptance test, the unit shall be retested to the extent necessary to verify the affected characteristics.

3.6 Test Sequence

The order of the functional test paragraphs as listed does not represent the required sequence of tests. Functional tests may be performed in any sequence. To facilitate testing, steps from one test paragraph may be performed in conjunction with steps from any other paragraph at the option of Hughes EDD.

3.7 Standard Test Conditions

Ambient test conditions for conducting acceptance tests shall be as indicated below unless otherwise specified.

a. Temperature, $65^{\circ}F$ to $85^{\circ}F$

b. Relative Humidity, 80% RH or less

c. Barometric Pressure, Prevailing Laboratory Pressure

3.8 Burn-In

Prior to the performance of final acceptance test, the TWT shall be burned-in for a period of six (6) cycles, each (8) hours in duration. Each cycle shall consist of the following:

a. Standby - One half (.5) hour

b. Full Operation - Six and one half (6.5) hours minimum

c. Off - One (1) hour minimum

3.9 RF Measurements

The TWT supply circuit shall be per Figure 1. RF measurements test equipment shall be per Figures 2A and 2B. Test conditions for individual tests shall be as specified.

For RF measurements the TWT input power will be set on the basis of an accurate power measurement obtained with the input thermistor mount and power meter and a subsequent adjustment of the precision variable attenuator. This adjustment is based on a known calibrated transfer characteristic of the RF input leg (Ref. Figure 2A, Items 11, 15, and 16).

3.0 REQUIREMENTS (Cont.)

3.9 RF Measurements (Cont.)

Output power measurements will be made on a pulse basis using a crystal detector which is calibrated at each frequency by a known reference signal. In the set-up of Figures 2A and 2B this reference level shall be established using the output power meter (at perhaps 1 milliwatt) with the waveguide switch set in the position opposite to that shown.

The reference signal level is obtained from the input test signal, samples at (5) and reinserted in the output leg at (11). This reference level is set by means of the variable attenuator (7) and read on the output power meter (22). The reference level is then modulated by the PIN diode modulator (9).

With the switch returned to the position shown, the reference signal is displayed on the oscilloscope as the output of a crystal detector (23). A notch in the reference signal video output of approximately 10 microseconds width is produced by the PIN diode modulator (9). By adjustment of the precision variable attenuators in the RF output leg, this notch shall be just filled in, indicating that the test and reference signals are of the same magnitude as the crystal detector. Using the precision variable attenuator settings and the known calibrated transfer characteristic of the RF output leg from the TWT to the waveguide switch input and to the thermistor mount, the TWT output power may be computed. Measurement of TWT input and output power provides for calculation of gain in the usual manner.

3.10 Test Equipment

EDD reserves the right to substitute listed test equipment with equipment of equivalent performance.

4.0 QUALITY CONFORMANCE INSPECTION, PART I (QCI-1)

The following tests shall be performed on each traveling wave tube (TWT); test data shall be recorded as specified in the individual test paragraph.

4.1 Operating Procedure

4.1.1 Cooling

The TWT gun is cooled by natural air convection. The collector and body are cooled by a minimum flow rate of 3 gallons per minute of FC77.

4.0 QUALITY CONFORMANCE INSPECTION, PART I (QCI-1) (Cont.)

4.1 Operating Procedure (Cont.)

4.1.2 Absolute Ratings

The TWT element parameters shall be within the following absolute limits. Operation outside of these limits may cause damage to the TWT.

	Min.	Max.	Units	Symbol	Notes
Ion Pump Voltage	2.7	5.0	kV	Eip	1
Heater Voltage	10.0	12.0	V	Ef	
Heater Current	--	7.0	A	If	2
Grid Bias Voltage**	-650	-350	V	Ec	
Peak Grid Pulse Voltage**	--	475	v	egk	
Cathode Voltage	-5*	+5*	%	Ek	
Peak Body Current	--	1.5	a	iw	
Collector Voltage***	--	-11.0	kV	Eb	
Duty Cycle	--	.05	--	Du	
Pulse Width	5	200	usec	tp	
Cathode Warm-up Time	300	--	sec	tk	3
RF Input Power	--	+3*	dB	Pi(rf)	
Peak arc Current	--	1000	A	ik	4
Inlet Cooling Fluid Temp.	-54	55	^{o}C	T	
Frequency	7.8	8.5	GHz	F	

*Variance from nameplate value
**Referred to cathode
***Referred to body

4.0 QUALITY CONFORMANCE INSPECTION, PART I (QCI-1) (Cont.)

4.1 Operating Procedure (Cont.)

4.1.2 Absolute Ratings (Cont.)

Notes:

1. Voltage shall be applied to the ion pump at all times that any other voltages are applied on the TWT. Ion pump voltage shall be 3.3 kV ± 10%. Ion pump supply must be capable of supplying 3.0 kV min at 100 μA.

2. Heater surge current must be limited externally to the value specified.

3. Heater cathode warm-up time is required before application of high voltage. A warm-up time of 300 seconds is required before specified characteristics apply.

4. The TWT will be protected by a current limiting resistor of TBS in series with the cathode and a spark gap which fires within 0.1 μsec after application of a voltage pulse of 1500V between grid and cathode.

4.1.3 Test Conditions (Notes 5 and 6)

Test Condition Notes 1-4	Ef V	Ec V	egk v Note 7	Ek kV	Du	Eb	tp μsec	Pi(rf) mW Note 4
1	N.P.	-450	N.P.	N.P.	0.05	N.P.	200	N.P.
2	N.P.	-450	N.P.	N.P.	0.05	N.P.	200	0

Notes:

1. N.P. - Nameplate Value
2. Adj. - Adjustable
3. Test Condition 1 shall be initiated as follows:
   a. Set Ef at N.P.
   b. Set Ec at N.P.
   c. Five (5) minutes after application of Ef adjust Ek, and Eb to nameplate values.
   d. Adjust egk to nameplate value.
   e. Set the signal generator at 8.15 GHz and adjust the TWT drive level to the nameplate value.

4.0 QUALITY CONFORMANCE INSPECTION, PART I (QCI-1) (Cont.)

4.1 Operating Procedure (Cont.)

4.1.3 Test Conditions (Note 5) (Cont.)

Notes (Cont.):

4. Nameplate value of Pi(rf) is the value of peak input RF power which provides a minimum peak output RF power of 20 kilowatts over the operating frequency of 7.9 to 8.4 GHz.

5. A minimum flow rate of 3 gallons per minute of FC77 shall be provided.

6. Voltage shall be applied to the ion pump at all times that any other voltages are applied to the TWT. Ion pump voltage shall be 3.3 kV ± 10%.

7. Grid pulse egk is referenced to the cathode. The total video pulse required will be the sum of egk and Ec.

4.1.4 Turn-On Procedure

CAUTION: Turn-on of the TWT shall always be performed in the following sequence:

1. Apply the rated ion pump voltage.
2. Apply cooling per Paragraph 4.1.1.
3. Apply the nameplate grid bias voltage.
4. Apply the nameplate heater voltage.

Do not allow the heater current to exceed 7.0 amperes during warm-up.

5. After 4.5 minutes minimum, apply the rated collector and body voltages.

6. Apply the nameplate grid pulse voltage at a maximum duty cycle of 0.001. Increase duty to applicable test condition.

7. Apply the required RF input power.

4.1.5 Turn-Off Procedure

Reverse the steps of Par. 4.1.4, omitting the time delay of Step 5.

4.2 Visual Inspection

The TWT shall be visually inspected for physical damage.

4.0 QUALITY CONFORMANCE INSPECTION, PART I (QCI-1) (Cont.)

4.3 Electrical Inspection

These tests shall be performed with the TWT operating at nameplate voltages (i.e., those operating voltages selected for optimum performance) unless otherwise specified. Cooling as specified in Par. 4.1.1. Test equipment per Figures 1 and 2 unless otherwise specified.

4.3.1 Heater Voltage (Ef)

Test Condition 1

The measured operating heater voltage shall be in the range of 10.0 to 12.0V. Record the value on the test data sheet.

4.3.2 Heater Current (If)

Test Condition 1

The measured operating heater current at the heater voltage established in Par. 4.3.1 shall be in the range of 3 to 5A. Record the value on the test data sheet.

4.3.3 Cathode Voltage (Ek)

Test Condition 1

The measured operating cathode voltage shall be in the range of TBS to TBS kV, referenced to the body. Record the value on the test data sheets.

4.3.4 Peak Body Current (iw)

Test Condition 1

The measured operating peak body current shall be no greater than 20% of the peak cathode current. Record the value on the test data sheet.

4.3.5 Peak Grid Voltage (egk)

Test Condition 1

Grid pulse (egk) is referenced to the cathode. The total required video pulse will be the sum of egk and Ec. The peak grid voltage shall be in the range of TBS to TBS volts with less than 700 nanosecond rise and fall times. Record the value on the test data sheets.

4.0 QUALITY CONFORMANCE INSPECTION, PART I (QCI-1) (Cont.)

4.3 Electrical Inspection (Cont.)

4.3.6 Peak Grid Current (ic)

Test Condition 1

The measured operating peak grid current shall be no greater than 0.1 ampere. Record the value on the test data sheet.

4.3.7 Collector Current (ib) and Voltage (Eb)

Test Condition 1

The measured operating peak collector current shall be no greater than TBS amperes. Record the value on the test data sheet. Also record the value of the collector voltage (Eb).

4.3.8 Peak Cathode Current (ik)

Test Condition 1

The measured operating peak cathode current shall be no greater than TBS amperes. Record the value on the test data sheet.

4.3.9 Peak Output Power

Test Condition 1 (Ref. Paragraph 3.8)

Step 1: Adjust the RF input power to nameplate. Record the value of RF input power on the test data sheet.

Step 2: Plot a graph of peak output power versus frequency. The peak output power over the frequency band 7.9 to 8.4 GHz shall be no less than 20 kw. Record the value of minimum and maximum output power on the test data sheet. Attach graph to data sheets.

4.3.10 Gain

Under the conditions of Par. 4.3.9, Steps 1 and 2, calculate the minimum gain over the frequency band 7.9 to 8.4 GHz. The minimum gain shall be no less than 53 dB. Record the value on the test data sheet.

4.0 QUALITY CONFORMANCE INSPECTION, PART I (QCI-1) (Cont.)

4.3 Electrical Inspection (Cont.)

4.3.11 Beam Efficiency (ηB)

From the data of Par. 4.3.3, 4.3.4, 4.3.7, and 4.3.9, calculate beam efficiency using the following formula:

$$\eta B = \frac{Po}{|(Ek)|\,|(iws)| + |(Eb)|\,|(ib)|}$$

where Eb is referenced to Ek

Beam efficiency shall be no less than 25%. Record the value on the test data sheet.

4.3.12 Phase Pushing - Grid Pulse Potential ($\Delta\phi/\Delta egk$)

Test Condition 1, F =8.15 GHz; test equipment per Figures 3 or 4.

Step 1: Adjust phase indicator, Item 4, Figure 3, to null, or phase shifter Item 29, Figure 4B for a null indication as observed on the oscilloscope Item 24, Figure 4B. Note phase shifter reading.

Step 2: Vary egk from the nameplate value by +25V. Read phase variation on phase indicator Figure 3 or readjust phase shifter Figure 4B for a null indication as observed on the oscilloscope. The phase shift is the difference between the readings of the phase shifter in Steps 1 & 2.

Step 3: Vary egk from the nameplate value by -25V. Read phase variation on phase indicator, Figure 3, or readjust phase shifter, Figure 4B, for a null indication as observed on the oscilloscope. The phase shift is the difference between the readings of the phase shifter in Steps 1 & 3.

Step 4: Calculate phase shift by adding the magnitude of the phase shift in Step 2 to the magnitude of the phase shift in Step 3, divide by 50V and multiply by egk. The phase shift shall be no greater than 2.5°/Volt. Record the value on the test data sheet.

4.3.13 Phase Pushing - Body to Cathode Potential ($\Delta\phi/\Delta Ek$)

Test Condition 1, F = 8.15 GHz; test equipment per Figures 3 or 4.

Step 1: Adjust phase indicator, Item 4, Figure 3, to null or phase shifter, Item 29, Figure 4B, for a null indication as observed on the oscilloscope, Item 24, Figure 4B. Note phase shifter reading.

4.0 QUALITY CONFORMANCE INSPECTION, PART I (QCI-1) (Cont.)

4.3 Electrical Inspection (Cont.)

4.3.13 Phase Pushing - Body to Cathode Potential ($\Delta\phi$ / Δ Ek) (Cont.)

Step 2: Vary Ek from the nameplate value by +1 kV. Read phase variation on phase indicator, Figure 3, or readjust phase shifter, Figure 4B, for a null indication as observed on the oscilloscope. The phase shift is the difference between the readings of the phase shifter in Steps 1 and 2.

Step 3: Vary Ek from the nameplate value by -1 kV. Read phase variation on phase indicator, Figure 3, or readjust phase shifter, Figure 4B, for a null indication as observed on the oscilloscope. The phase shift is the difference between the readings of the phase shifter in Steps 1 and 3.

Step 4: Calculate phase shift by adding the magnitude of the phase shift in Step 2 to the magnitude of the phase shift in Step 3 and divide by 2 kV and multiply by Ek. The phase shift shall be no greater than .16°/ Volt. Record the value on the test data sheet.

4.3.14 Phase Pushing - RF Drive Power ($\Delta\phi$ / Δ Pi(rf))

Test Condition 1, F = 8.15 GHz; test equipment per Figures 3 or 4

Step 1: Adjust phase indicator, Item 4, Figure 3, to null, or phase shifter, Item 29, Figure 4B, for a null indication as observed on the oscilloscope, Item 24, Figure 4B. Note phase shifter reading.

Step 2: Vary Pi(rf) by -10 dB. Read phase variation on phase indicator; Figure 3, or readjust phase shifter, Figure 4B, for a null indication as observed on the oscilloscope. The phase shift is the difference between the readings of the phase shifter in Steps 1 and 2.

Step 3: Calculate phase shift by dividing the indication of Step 2 by 10 dB. The phase shift shall be no greater than 6° per dB change in RF input power. Record the value on the test data sheet.

4.0 QUALITY CONFORMANCE INSPECTION, PART I (QCI-1) (Cont.)

4.3 Electrical Inspection (Cont.)

4.3.15 Phase Linearity

Test Condition 1; test equipment per Figure 3 except VSWR = 1.25:1 at input and output of TWT.

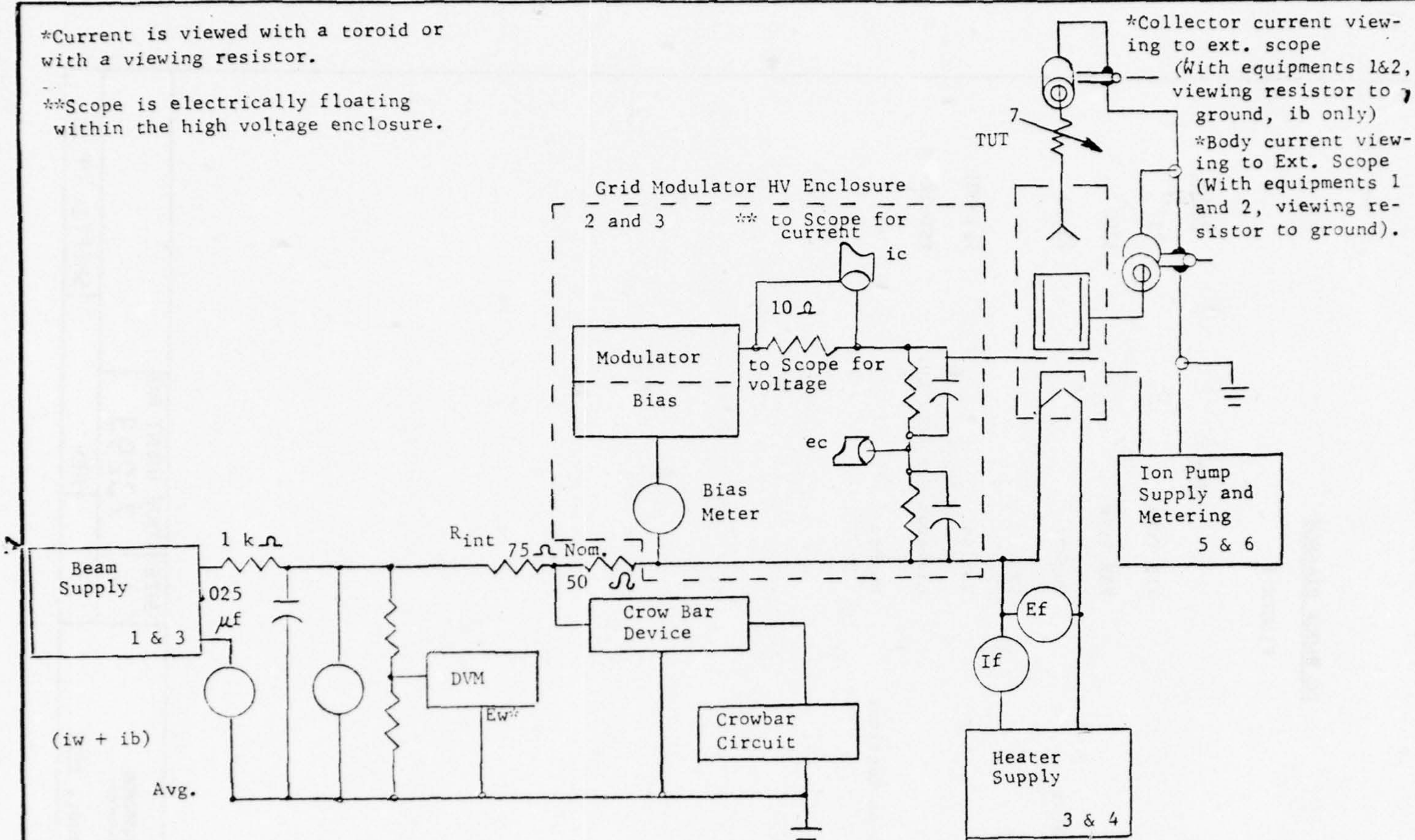
Step 1: Calibrate the X-Y recorder by replacing the TWT with a length of waveguide and a phase shifter equivalent to the calculated electrical length of the tube. Adjust phase shifter in 5^{o} increments to provide calibration lines on the graph paper.

Step 2: Replace the waveguide and phase shifter with the TWT. Record the phase information from 7.9 to 8.4 GHz.

Step 3: Phase linearity is the peak deviation from the constant phase calibration rotated as necessary to compensate for linear phase shift versus frequency. The phase linearity shall be no greater than $\pm 15^{o}$ maximum over the full band (7.9 to 8.4 GHz). Record the value on the test data sheet.

4.3.16 X-Ray Emission

With the TWT operating per Test Condition 1, measure X-rays emitted with the Victoreen Instrument Company Survey Meter Model 440 or equivalent. Record the value on the test data sheet.



DC BLOCK DIAGRAM
FIGURE 1

HUGHES — HUGHES AIRCRAFT COMPANY — ELECTRON DYNAMICS DIVISION, 3100 West Lomita Boulevard, Torrance, California 90509	SIZE A	CODE IDENT NO 73293	
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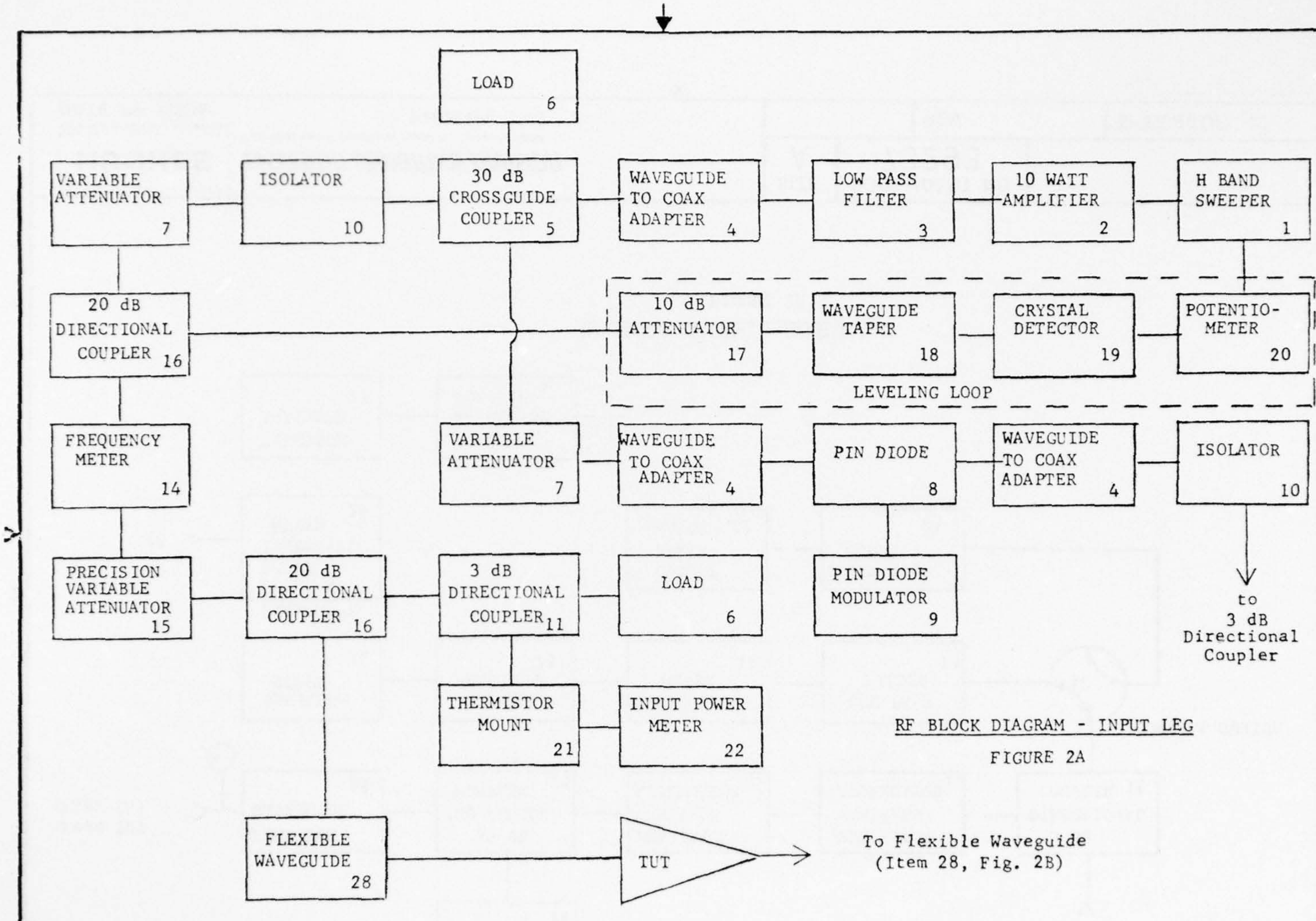
DC BLOCK DIAGRAM

FIGURE 1

	Equipment	Make	Model
1.	Beam Supply	FXR Type	5227
2.	Modulator	FXR Type	5202
3.	Supply and Modulator	Hughes	73293
4.	Heater Supply	FXR	--
5.	Ion Pump Supply	Varian	921-001
6.	Ion Pump Supply	Elektron Projects Co.	PSD-3K-1M
7.	Variable Depression Resistor	Hughes	--



RF BLOCK DIAGRAM - INPUT LEG

FIGURE 2A

HUGHES — HUGHES AIRCRAFT COMPANY	ELECTRON DYNAMICS DIVISION — 3100 West Lomita Boulevard, Torrance, California 90509	SIZE A	CODE IDENT NO 73293
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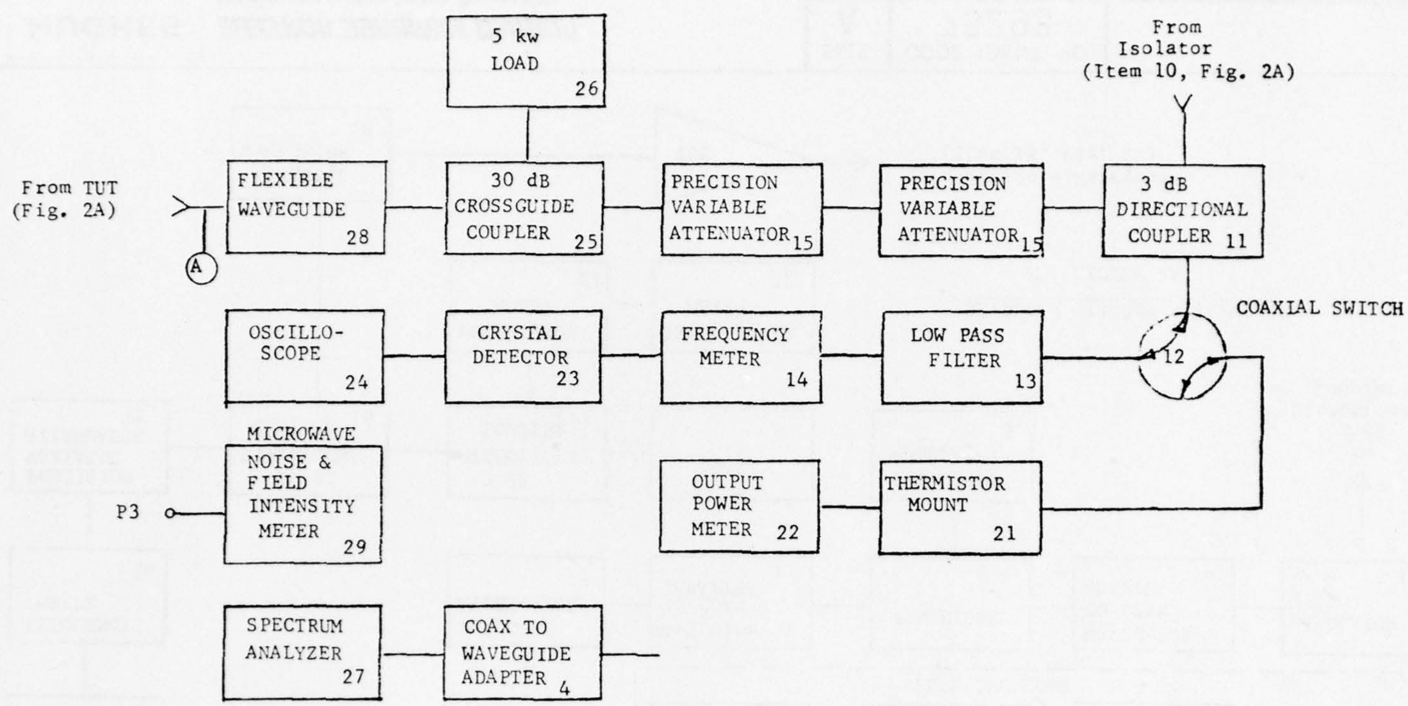


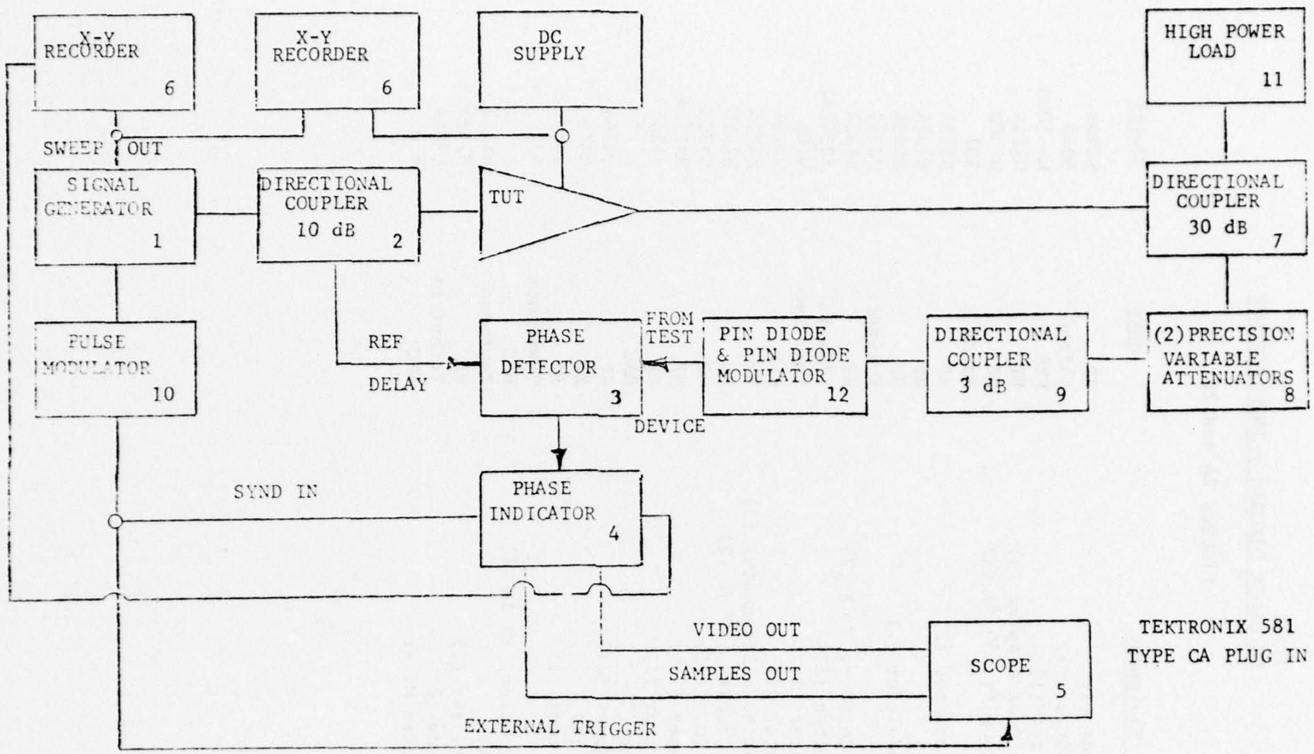
RF BLOCK DIAGRAM - OUTPUT LEG

FIGURE 2B

RF BLOCK DIAGRAM - INPUT/OUTPUT

FIGURES 2A and 2B

	List of Equipment	Make	Model
1.	H-Band Sweeper (1)	HP	8690B
2.	10 Watt Amplifier (1)	Alfred	5040
3.	Low Pass Filter (1)	FXR	LA-100N
4.	Waveguide to Coax Adapter (4)	HP	H421A
5.	Crossguide Coupler, 30 dB (1)	HP	H750D
6.	Load (2)	Narda	301
7.	Variable Attenuator (2)	HP	H375A
8.	PIN Diode (1)	HP	8403A
9.	PIN Diode Modulator (1)	HP	8403A
10.	Isolator (2)	Sylvania	FC512
11.	Directional Coupler, 3 dB (2)	HP	H752A
12.	Waveguide Switch (1)	Silvers	7020/42
13.	Low Pass Filter (1)	Sage Lab	W10A
14.	Frequency Meter (2)	FXR	W410A
15.	Precision Variable Attenuator (3)	HP	H382A
16.	Directional Coupler, 20 dB (2)	HP	H752D
17.	Attenuator, 10 dB (1)	HP	H370C
18.	Waveguide Taper (1)	HP	HX212A
19.	Crystal Detector (1)	HP	X424A
20.	Potentiometer (1)	HAC	
21.	Thermistor Mount (2)	HP	H486A
22.	Power Meter (2)	HP	431B
23.	Crystal Detector (1)	HP	H421A
24.	Scope (1)	Tektronix	531
25.	Crossguide Coupler, 30 dB (1)	HAC	
26.	5 KW Load (1)	Raytheon	LXH12
27.	Spectrum analyzer (1)	HP	8551A
28.	Flex Waveguide (2)	Technicraft	87864
29.	Microwave Noise Meter	EMC	910



PHASE LINEARITY AND
PHASE PUSHING BLOCK DIAGRAM

FIGURE 3

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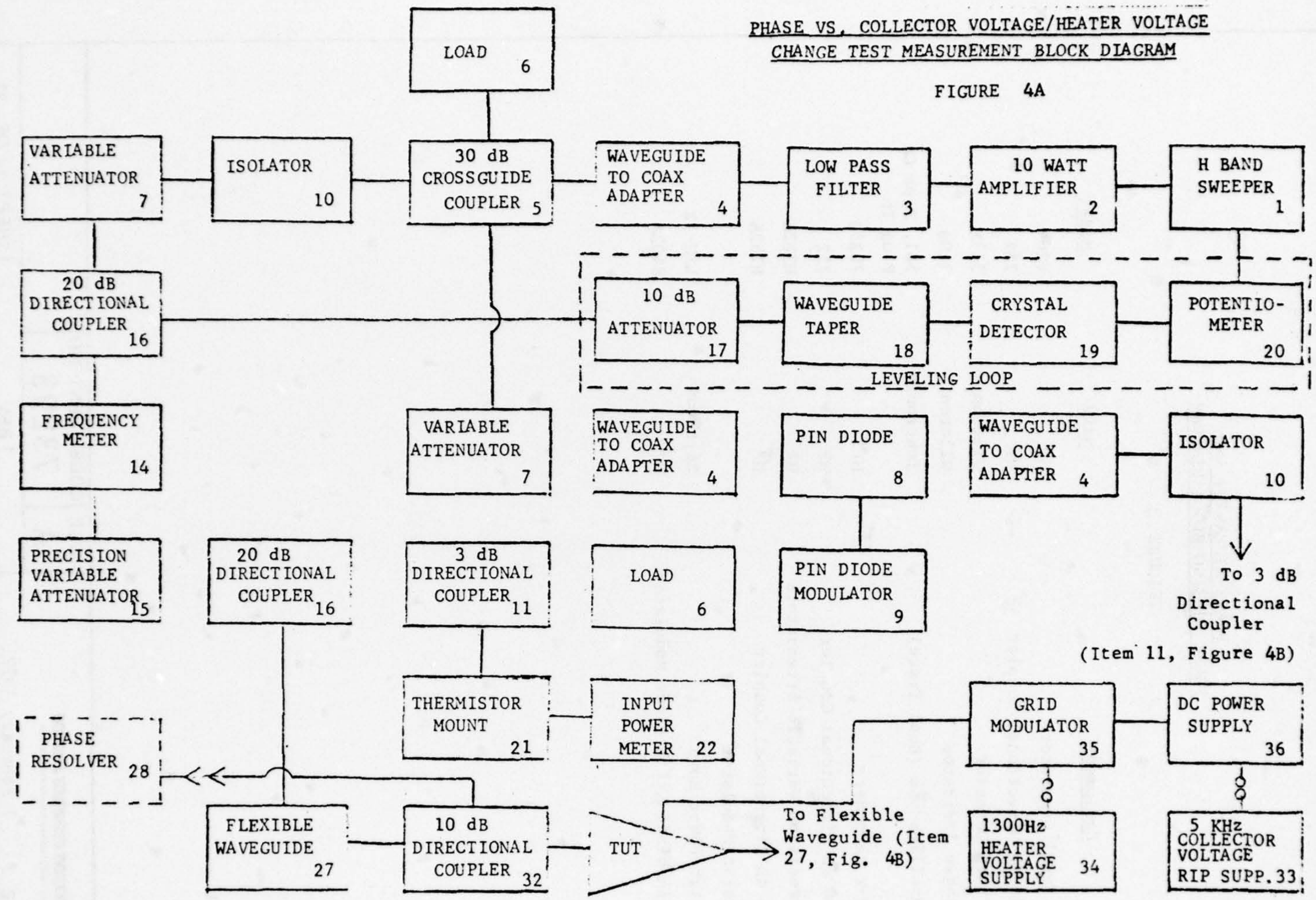
PHASE LINEARITY AND
PHASE PUSHING BLOCK DIAGRAM

FIGURE 3

	Equipment	Make	Model
1.	Signal Generator	HP	620A
2.	10 dB Directional Coupler	HP	752
3.	Phase Detector	Wiltron	311X
4.	Phase Indicator	Wiltron	310B
5.	Oscilloscope (Dual Trace)	Tektronix	581, Type CA Plug In
6.	X-Y Recorder	HP	7035B
7.	30 dB Directional Coupler	HP	752
8.	Precision Variable Attenuators	HP	H382A
9.	3 dB Directional Coupler	HP	H752A
10.	Pulse Modulator		
11.	High Power Load	Raytheon	LXH-12
12.	Pin Diode & Pin Diode Modulator	HP	8403A

PHASE VS. COLLECTOR VOLTAGE/HEATER VOLTAGE CHANGE TEST MEASUREMENT BLOCK DIAGRAM

FIGURE 4A



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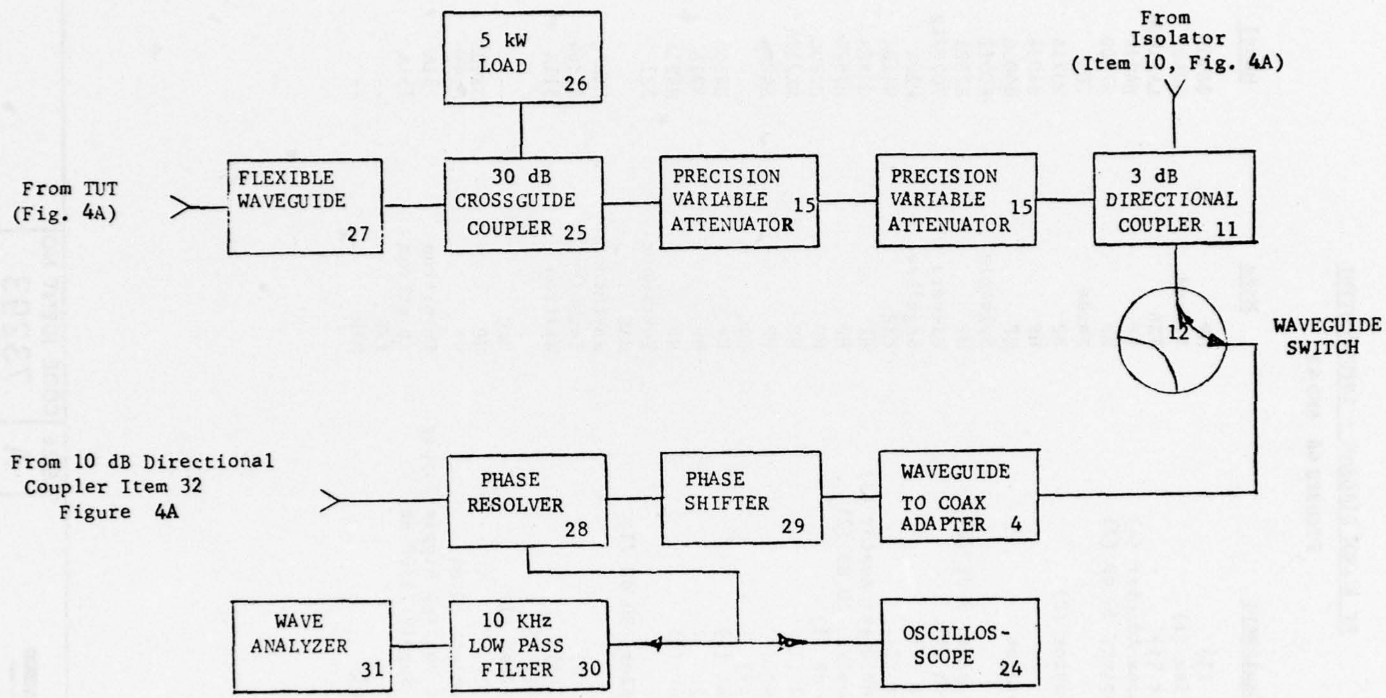


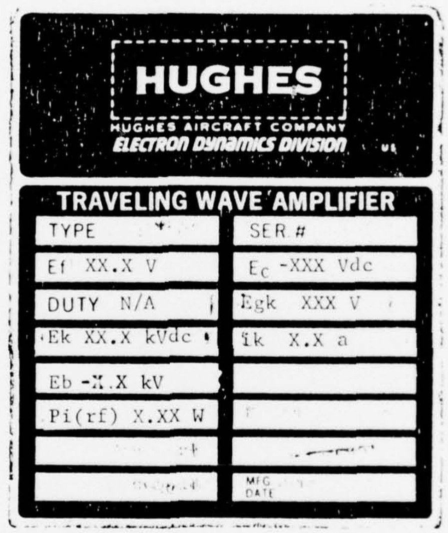
PHASE VS. COLLECTOR VOLTAGE/HEATER VOLTAGE CHANGE TEST MEASUREMENT BLOCK DIAGRAM

FIGURE 4B

RF BLOCK DIAGRAM - INPUT/OUTPUT

FIGURES 4A AND 4B

	List of Equipment	Make	Model
1.	H-Band Sweeper (1)	HP	8690B
2.	10 Watt Amplifier (1)	Alfred	5040
3.	Low Pass Filter (1)	FXR	LA-100N
4.	Waveguide to Coax Adapter (4)	HP	H421A
5.	Crossguide Coupler, 30 dB (1)	HP	H750D
6.	Load (2)	Narda	301
7.	Variable Attenuator (2)	HP	H375A
8.	PIN Diode (1)	HP	8403A
9.	PIN Diode Modulator	HP	8403A
10.	Isolator (2)	Sylvania	FC512
11.	Directional Coupler, 3 dB (2)	HP	H752A
12.	Waveguide Switch (1)	Silvers	7020/42
13.	Low Pass Filter (1)	Sage Lab	W10A
14.	Frequency Meter (2)	FXR	W410A
15.	Precision Variable Attenuator (3)	HP	H382A
16.	Directional Coupler, 20 dB (2)	HP	H752D
17.	Attenuator, 10 dB (1)	HP	H370C
18.	Waveguide Taper (1)	HP	HX212A
19.	Crystal Detector (1)	HP	X424A
20.	Potentiometer (1)	HAC	
21.	Thermistor Mount (1)	HP	H486A
22.	Power Meter (1)	HP	431B
23.	Crystal Detector (1)	HP	H421A
24.	Scope (1)	Tektronix	531
25.	Crossguide Coupler, 30 dB (1)	HAC	
26.	5 KW Load (1)	Raytheon	LXH12
27.	Flex Waveguide (2)	Technicraft	87864
28.	Phase Resolver (1)	Wiltron	311X
29.	Phase Shifter (1)		
30.	10 KHz L. P. Filter (1)	HAC	--
31.	Wave Aanlyzer (1)	HP	3590A
32.	Directional Coupler, 10 dB	HP	H752C
33.	5 KHz Collector Voltage Ripple Supply	Invertron	751A
34.	Heater Voltage Supply (1300 Hz)	Invertron	751A
35.	Grid Modulator	FXR	--
36.	Beam Power Supply	FXR	--



HUGHES ELECTRON DYNAMICS DIVISION 3100 West Lomita Boulevard, Torrance, California 90509	SIZE A	CODE IDENT NO 73293	
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APPENDIX 2

8726H ENGINEERING TEST DATA SHEET

HUGHES ELECTRON DYNAMICS DIVISION
HUGHES AIRCRAFT COMPANY
3100 West Lomita Boulevard, Torrance, California 90509. Tel (213) 534-2121

DATA SHEET NO.
PRODUCT TWT
MODEL 8726H
PART NO.

ENGINEERING TEST DATA SHEET

CODE IDENT. 73293

TEST NAME	SPEC. No.	TEST POS. No.	SERIAL No.
		191.20	6001

REV.	AUTHORITY	DATE	APPROVAL	REV.	AUTHORITY	DATE	APPROVAL

QUALITY	DATE OF ISSUE	EFFECTIVITY
	2 March 1977	PART I (QCI-1) QUALITY CONFORMANCE INSPECTION

ITEM	SPEC. PAR. No.	TEST DESIGNATION	TEST CONDITION / DESCRIPTION		R/C	MIN.	DATA	MAX.	UNITS
	3.8	Burn-In	Burn-In 6 cycles each 8 hours in duration completed Date started 3-20-77 Date completed 3-25-77		C	--	✓	--	--
	4.3.1	Heater Voltage	Test Condition 1	Ef	R	10.0	10.0	12.0	V
	4.3.2	Heater Current	Test Condition 1 Ef equal to value established in Par. 4.3.1	If	R	3	5.3	7	A
	4.3.3	Cathode Voltage (referenced to body)	Test Condition 1	Ek	R	-24.5	-25.4	-26.5	kV
	4.3.4	Peak Body Current	Test Condition 1	iw	R	--	0.80	0.2ik	a
	4.3.5	Peak Grid Voltage (referenced to cathode)	Test Condition 1	egk	R	350	410	475	v
	4.3.6	Peak Grid Current	Test Condition 1	ic	R	--	0.004	0.1	a
	4.3.7	Collector Current and Voltage	Test Condition 1	ib	R	--	4.40	5.5	a
				Eb	R	--	-10.0	-11.0	kV
	4.3.8	Peak Cathode Current	Test Condition 1	ik	R	--	5.2	5.5	a

HUGHES ELECTRON DYNAMICS DIVISION
HUGHES AIRCRAFT COMPANY
3100 West Lomita Boulevard, Torrance, California 90509, Tel (213) 534-2121

DATA SHEET NO.

REV.

SERIAL NO.

ENGINEERING TEST DATA SHEET

CODE IDENT. 73293

MODEL 8726H

ITEM	SPEC. PAR. No.	TEST DESIGNATION	TEST CONDITION / DESCRIPTION	R/C	MIN.	DATA	MAX.	UNITS
	4.3.9	Peak Output Power	Test Condition 1 Pi(rf) = N.P. F = 7.9 to 8.4 GHz					
			Pi(rf)	R	--	0.10	--	W
			po (min)	R	20	23.2	--	kw
			po (max)	R	20	27.8	--	kw
			Attach graph	C	--	✓	--	--
	4.3.10	Gain	From data of Par. 4.3.9, Steps 1 and 2 calculate gain F = 7.9 to 8.4 GHz					
			G (min)	R	53	53.7	--	dB
	4.3.11	Beam Efficiency	η B	R	25	26.3	--	%
	4.3.12	Phase Pushing Grid Pulse Potential	Test Condition 1; F = 8.15 GHz egk varied ± 25v from N.P. $\frac{\Delta\emptyset}{\Delta egk}$	R	--	0.60	2.5	o/v
	4.3.13	Phase Pushing Body to Cathode Potential	Test Condition 1; F = 8.15 GHz Ek varied ± 1 kV from N.P. $\frac{\Delta\emptyset}{\Delta Ek}$	R	--	0.097	0.16	o/V
	4.3.14	Phase Pushing RF Drive Power	Test Condition 1; F = 8.15 GHz Pi(rf) varied -10 dB from N.P. $\frac{\Delta\emptyset}{\Delta Pi(rf)}$	R	--	2.75	6	o/dB
	4.3.15	Phase Linearity	Test Condition 1; VSWR = 1.25:1 at input and output F = 7.9 to 8.4 GHz $\Delta\emptyset$	R	--	± 8	±15	deg
	4.3.16	X-Ray Emission	Test Condition 1 X-Rad	R	--	0.4	--	mr/hr
	4.2	Visual Inspection	Visually inspect for physical damage	C	--	✓	--	--

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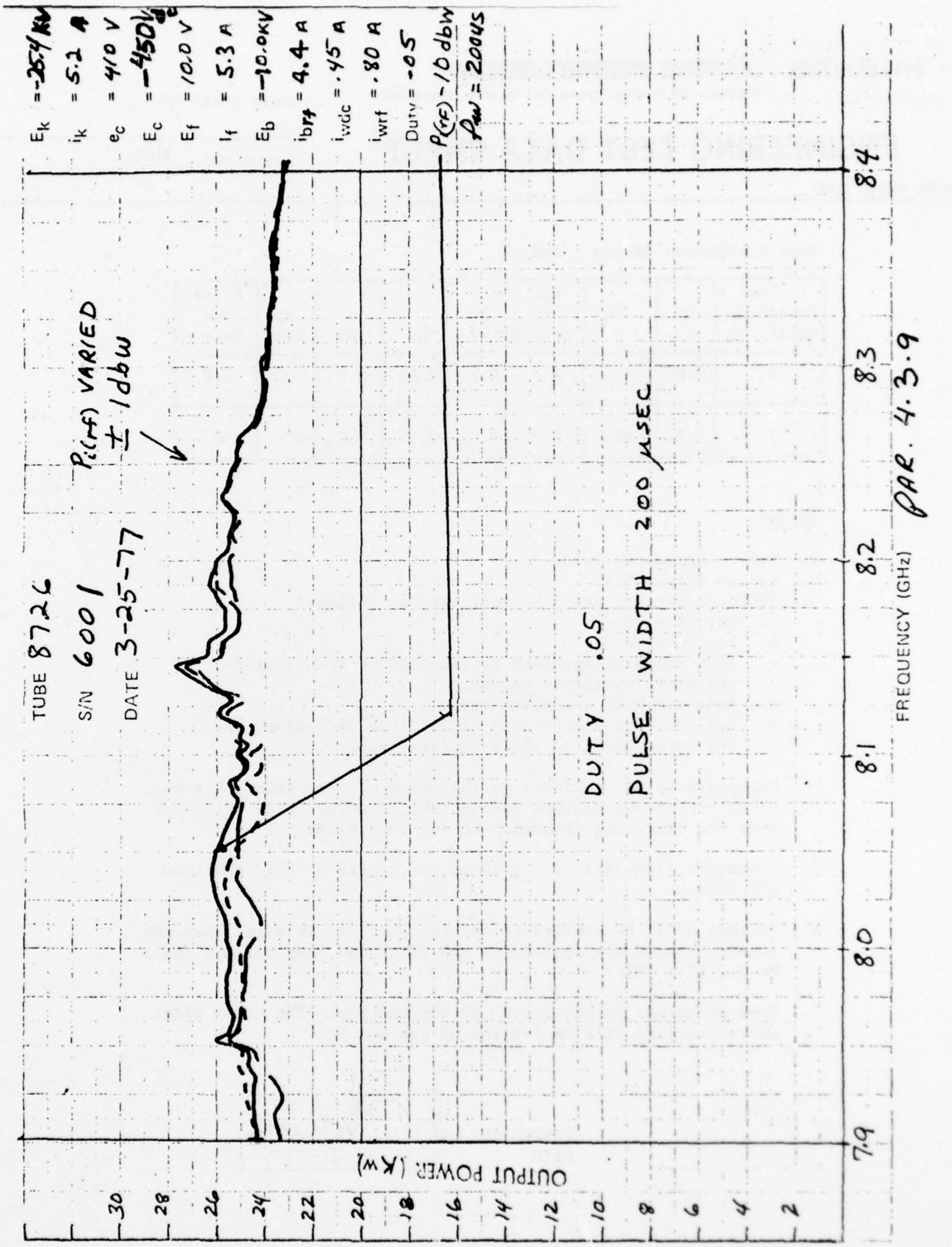
TUBE 872C
S/N 6001
DATE 3-25-77
$P_{i(rf)}$ VARIED
± 1dbw
DUTY .05
PULSE WIDTH 200 μSEC
E_k = -25.4 KV
i_k = 5.2 A
e_c = 410 V
E_c = -450 Vdc
E_f = 10.0 V
I_f = 5.3 A
E_b = -10.0 KV
i_{brf} = 4.4 A
i_{wdc} = .45 A
i_{wrf} = .80 A
Duty = .05
$P_{(rf)}$ -10 dbw
P_w = 200 μs
OUTPUT POWER (KW)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
7.9
8.0
8.1
8.2
8.3
8.4
FREQUENCY (GHz)
PAR. 4.3.9

HUGHES HUGHES AIRCRAFT COMPANY

ELECTRON DYNAMICS DIVISION

3100 West Lomita Boulevard, Torrance, California 90509, Tel (213) 534-2121

ENGINEERING TEST DATA SHEET

CODE IDENT. 73293

DATA SHEET NO.

REV.

SERIAL NO. 6001

Test Conditions (Notes 5 and 6)

Test Condition Notes 1-4	EF V	Ec V	egk v Note 7	Ek kV	Du	Eb	tp sec	Pi(rf) mW Note 4
1	N.P.	-450	N.P.	N.P.	0.05	N.P.	200	N.P.
2	N.P.	-450	N.P.	N.P.	0.05	N.P.	200	0

Notes:

1. N.P. - Nameplate Value
2. Adj. - Adjustable
3. Test Condition 1 shall be initiated as follows:
   a. Set Ef at N.P.
   b. Set Ec at N.P.
   c. Five (5) minutes after application of Ef adjust Ek, and Eb to nameplate values.
   d. Adjust egk to nameplate value.
   e. Set the signal generator at 8.15 GHz and adjust the TWT drive level to the nameplate value.

4. Nameplate value of Pi(rf) is the value of peak input RF power, which provides a minimum peak output RF power of 20 kilowatts over the operating frequency of 7.9 to 8.4 GHz.

5. A minimum flow rate of 3 gallons per minute of FC77 shall be provided.

6. Voltage shall be applied to the ion pump at all times that any other voltages are applied to the TWT. Ion pump voltage shall be 3.3 kV ± 10%.

7. Grid pulse egk is referenced to the cathode. The total video pulse required will be the sum of egk and Ec.

TESTED BY G. Chavez

DATE 3-25-77

MISSION

of

Rome Air Development Center

RADC plans and conducts research, exploratory and advanced development programs in command, control, and communications (C^3) activities, and in the C^3 areas of information sciences and intelligence. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

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